PRINCIPLE DESIGN OF AN ENERGY EFFICIENT TRANSFEMORAL PROSTHESIS

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Abstract

In the pursuit of realizing an energy efficient transfemoral prosthetic, in this paper we present a preliminary study on a principle design. In particular, the design is based on the idea that the efficiency of the system can be realized by energetically coupling the knee and the ankle joints. In order to allow the energy transfer during the normal walking, we propose to introduce continuous controllable springs, which basically act as passive actuators.

1 Working Principle of the Prosthesis

In the design research field, especially related with robotics and bio-mechanics, there are many research studies on lower limb prosthesis design, since impact of the outcomes to the human life is crucial [1,2]. However, energy efficiency and mobility of the lower limb prosthesis are still open issues that should be deeply addressed. Besides those important criteria, authors could not find any design that couples the knee and ankle joint with the proper kinetic and kinematic behavior for push-off. Therefore, a principle design, which is inspired by the energetics of walking presented in [3], is introduced in this study.

In order to grasp the nature of walking from an energy point of view, a power analysis of the human gait has been given in Fig.1, from [3]. In particular, the figures shows the energy rate related with knee and ankle joints for one stride of natural cadence can be seen in this figure.

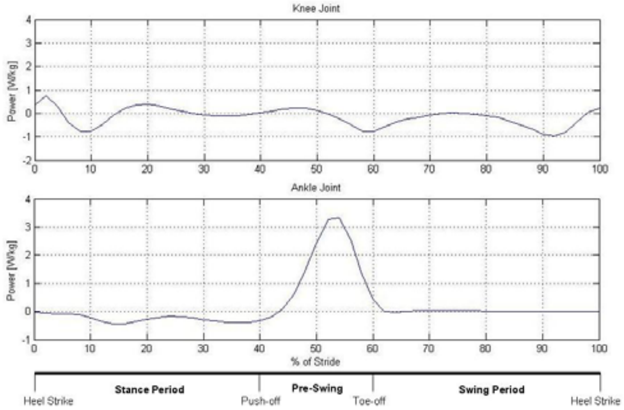

Fig. 1. Power analyses of knee and ankle in normal cadence. [3]

It can be seen that the knee joint is mainly a power absorber whereas the ankle joint is a generator. By analyzing the figure it can be noticed that the knee uses almost all of the energy that is absorbed during the stance phase of the gait for itself. Meanwhile, the ankle joint absorbs power by weight bearing. Afterwards, the knee absorbs power during in the early swing phase and in the late phase of the swing, while the ankle generates the main part of the power for the push-off in the pre-swing phase. This brief information explains the importance of the relation between knee and ankle joint. Coupling of these two joints can provide efficient and natural walking for prosthetic design. Depending on these observations, two storage phases are important for the design of a prosthesis which provides the torque for push-off. One is the swing phase of the knee and the other one is the roll-over phase of the ankle.

Following this analysis, we propose a working principle, which forms the prosthesis itself, and it is given in flow diagram representation in Fig. 2.

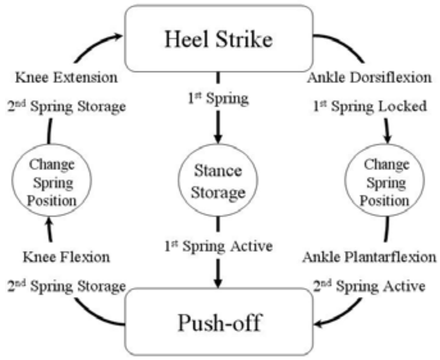

Fig. 2. Flow diagram representation of the working principle

There are two spring elements which one is at the ankle joint for the energy storage during roll-over. Second one couples the knee and ankle joint and is loaded during the first part of the swing phase. After reaching the max flexion, position of the spring is changed for the storage of the second part of the swing phase. After heel strike, 2^{nd} spring is locked and its position is changed without changing its length (free motion) to the release point for push-off.

References

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